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Rüdiger Hell • Ralf-Rainer Mendel
Editors

Cell Biology of Metals and Nutrients

Springer

Editors
Prof. Dr. Rüdiger Hell
Universität Heidelberg
Heidelberger Institut für
Pflanzenwissenschaften
Im Neuenheimer Feld 360
69120 Heidelberg
Germany
rhell@hip.uni-heidelberg.de

Prof. Dr. Ralf-Rainer Mendel
Technische Universität Braunschweig
Institut für Pflanzenbiologie
Humboldtstr. 1
38106 Braunschweig
Germany
r.mendel@tu-bs.de

Series Editor
David G. Robinson
Ruprecht-Karls-University of Heidelberg
Heidelberger Institute for Plant Sciences (HIP)
Department Cell Biology
Im Neuenheimer Feld 230
69120 Heidelberg
Germany

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Cover photo: The upper part of the cover was created by Steffen Rump. It shows a mitochondrion which is essential for the biosynthesis of two metal-containing prosthetic groups: the molybdenum cofactor (left) and iron sulfur clusters (middle).

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About the Editors

Rüdiger Hell studied Biology at the Technical University of Darmstadt, Germany, and completed his PhD at the University of Cologne, Germany, in 1989. From 1990 to 1992, he worked at the University of California in Berkeley as a postdoctoral researcher. After returning to Germany, he completed his postdoctoral thesis at the University of Bochum, in 1998, and held a position at the Leibniz Institute for Plant Genetics and Crop Plant Research in Gatersleben. During that time, he developed his ongoing interest in molecular mechanisms of plant nutrition, especially in sulfur metabolism and cellular redox control. In 2003, he was appointed chair at the Heidelberg Institute for Plant Sciences. He served as Dean of the Faculty of Biosciences at Heidelberg University from 2005 to 2007, and is currently the managing director of the university's Plant Sciences Institute.

Ralf-Rainer Mendel studied biochemistry at the Humboldt University in Berlin, completed his PhD at the Martin-Luther-University Halle in 1979 and his postdoctoral thesis, in 1985. During that time he held a position at the Institute for Plant Genetics and Crop Plant Research in Gatersleben.

In 1992, he was appointed as Full Professor of Botany at the (now) Institute of Plant Biology of the Braunschweig University of Technology, Germany. He has been the director of the Institute since 1993 and also served as Dean of Biosciences at Braunschweig from 1997 to 1999. His research focuses on the cell biology and biochemistry of molybdenum in plants and humans.

Preface

Plants are composed of 17 essential elements and these must be taken up as nutrients to allow for growth and cell division. Macronutrients are defined by their large amounts in plants ($>0.1\%$ of dry mass), while micronutrients are much less abundant ($<0.01\%$ of dry mass). C, H and O provide the bulk of biomass but only N, P, K, S, Ca and Mg (in decreasing order of abundance) are considered macronutrients in a strict sense. The micronutrients (Fe, Zn, Cu, Mn, B, Mo, Ni and Cl) are much more heterogeneous with respect to chemistry and biological function: the presence of Ni appears to be required in only one or two processes while the content of Mo is the lowest of the essential nutrients found in a plant. Metals are found in both groups and reflect their multiple catalytic and electron transfer functions in interaction with high and low molecular organic compounds in cells. Hence, the terms metals and nutrients are partially overlapping without precisely characterizing macro- and micronutrients. In addition, so-called beneficial elements are known to promote growth in only some taxa. This term refers to Al, C, Na, Se, and Si, the latter particularly being required by monocotyledonous plants. Other elements are taken up by plants but have no proven function or are even deleterious such as heavy metals.

Much effort has been devoted to study the physiology and biochemistry of metals and nutrients in plants. The aspect of cell biology, however, is an emerging new field, and even a new Gordon Research Conference (Cell Biology of Metals) has been launched recently. While N and S are structural and functional components of proteins, P is crucial for nucleic acids and energy metabolism, Ca, K, Cl, B and the metals are of key importance for a large number of biological reactions. These include photosynthesis, cell pressure, metabolic catalysis, oxygen transport, anabolism and catabolism, redox reactions, cell signalling, etc. Both the regulatory networks and the nutrient aspect of these elements have been successfully investigated using nutrient-deficiency experiments and transcriptome, proteome and metabolome tools as well as targeted approaches. However, much needs to be learnt about nutrient sensing, long-distance communication within the plant and cellular signal transduction chains in response to environmental stress.

With respect to metals, major progress has been made in recent years in our understanding of the biosynthesis of metal-containing prosthetic groups. Complex and multistep biosynthetic pathways were uncovered in greater detail. Progress has also been made in the identification of cellular sites of prosthetic groups' synthesis. However, our knowledge is scarce with respect to the steps subsequent to biosynthesis. It is largely unknown how these prosthetic groups are allocated, transported and directed to various cellular destinations, ultimately finding their way into the correct cognate proteins. There must be a plethora of transporters, chelators, metal cofactors, protein folding chaperones, metallochaperones, carrier proteins, storage proteins, and insertases involved. Another important objective is to understand how protein trafficking pathways and metal trafficking pathways are integrated and intersect. Further areas of focus are mechanisms of metal ion homeostasis, how cells sense diverse metal ions, how homeostatic mechanisms for different metal ions are integrated at the molecular and cellular level, and how the finely tuned interplay of these components ensures safe transport. Clearly, cellular malfunction, and consequently, disease are the result if any of the various key steps in metals allocation and insertion are perturbed and reduced cell division, growth proliferation and overall performance result from deficiencies of these nutrients.

This book emphasizes the cellular biology of metals and nutrients to provide a new concept that reaches beyond plant nutrition and plasmalemma transport but into cellular physiology. Each chapter contains basic information about uptake, physiological function, deficiency and toxicity syndromes, long-distance communication, and intracellular transport. The chapters are devoted to metals and nutrients where recent progress has been made and highlight the aspects of homeostasis and sensing, signalling, and regulation with cross-references to other organisms including humans. Where gaps are identified in our knowledge, these are pointed out and future research directions envisaged.

October 2009

Rüdiger Hell
Ralf-Rainer Mendel

Contents

Contributors

Oliver Batistič Universität Münster, Institut für Botanik und Botanischer Garten, Schlossplatz 4, 48149 Münster, Germany, oliver.batistic@uni-muenster.de

Florian Bittner Department of Plant Biology, Technical University of Braunschweig, Humboldtstrasse 1, 38106 Braunschweig, Germany

Alejandra Chacon-López Departamento de Ingeniería Genética de Plantas, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Irapuato, Guanajuato, México

Stephan Clemens Universität Bayreuth, Lehrstuhl Pflanzenphysiologie, Universitätsstrasse 30, 95440 Bayreuth, Germany

Christopher M. Cohu Biology Department, Colorado State University, Fort Collins, CO 80523-1878, USA

Françoise Daniel-Vedele Institut Jean-Pierre Bourgin (IJPB), Institut National de Recherche Agronomique (INRA), route de St Cyr, F-78026 Versailles, France, vedele@versailles.inra.fr

Toru Fujiwara Biotechnology Research Center, University of Tokyo, Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan; SORST, JST, Japan, atorufu@mail.ecc.u-tokyo.ac.jp

Mary Lou Guerinot Department of Biological Sciences, Dartmouth College, Hanover, NH 03755, Guerinot@Dartmouth.edu

Rüdiger Hell University of Heidelberg, Heidelberg Institute for Plant Sciences, Im Neuenheimer Feld 360, 69120 Heidelberg, Germany, rhell@hip.uni-heidelberg.de

Luis Herrera-Estrella Laboratorio Nacional de Genómica para la Biodiversidad, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Irapuato, Guanajuato, México, lherrera@ira.cinvestav.mx

Werner M. Kaiser Julius-von-Sachs-Institut für Biowissenschaften, Lehrstuhl für Botanik I, Julius-von-Sachs-Platz 2, D-97082 Würzburg, Germany, kaiser@botanik.uni-wuerzburg.de

Alison J. Karley Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, UK

M. Sayyar Khan Department of Plant Breeding and Genetics, NWFP Agricultural University Peshawar, Pakistan

Anne Krapp Institut Jean-Pierre Bourgin (IJPB), Institut National de Recherche Agronomique (INRA), route de St Cyr, F-78026 Versailles, France, krapp@versailles.inra.fr

Jörg Kudla Universität Münster, Institut für Botanik und Botanischer Garten, Schlossplatz 4, 48149 Münster, Germany, jkudla@uni-muenster.de

Ralf-Rainer Mendel Department of Plant Biology, Technical University of Braunschweig, Humboldtstrasse 1, 38106 Braunschweig, Germany, r.mendel@tu-bs.de

Kyoko Miwa Hokkaido University, Creative Research Initiative Sousei, Kita-ku, Sapporo, miwakyoko@cris.hokudai.ac.jp

Claudia-Anahí Pérez-Torres Laboratorio Nacional de Genómica para la Biodiversidad, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Irapuato, Guanajuato, México

Marinus Pilon Biology Department, Colorado State University, Fort Collins, CO 80523-1878, USA, pilon@lamar.colostate.edu

Elizabeth A.H. Pilon-Smits Biology Department, Colorado State University, Anatomy/Zoology Building, Fort Collins, CO, 80523, USA, epsmits@lamar.colostate.edu

Jon K. Pittman Faculty of Life Sciences, University of Manchester, Michael Smith Building, Oxford Road, Manchester M13 9PT, UK, jon.pittman@manchester.ac.uk

Colin F. Quinn Biology Department, Colorado State University, Anatomy/Zoology Building, Fort Collins, CO, 80523, USA, cquinn@lamar.colostate.edu

Lenin Sánchez-Calderón Laboratorio Nacional de Genómica para la Biodiversidad, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Irapuato, Guanajuato, México

Philip J. White Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, UK, philip.white@scri.ac.uk

Lorraine E. Williams School of Biological Sciences, University of Southampton, Southampton SO16 7PX, UK, lew@soton.ac.uk

Markus Wirtz University of Heidelberg, Heidelberg Institute for Plant Sciences, Im Neuenheimer Feld 360, 69120 Heidelberg, Germany